Searching for Interstellar Pickup Ions in the Solar Wind Using Cassini's Plasma Spectrometer

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Overview

Cassini's Ion Mass Spectrometer (IMS) is collecting solar wind data (mass per charge, energy per charge, direction, and number of ions) as it travels to Saturn. Interstellar Pickup Ions, photoionized gas from the Interstellar Medium (ISM), can be distinguished from solar ions by their velocity distribution. The project objective is to simplify Cassini data analysis by writing and using IDL programs to manipulate data, generate useful graphs, and identify the direction and number of Interstellar Pickup Ions.

Background

Cassini's Ion Mass Spectrometer (IMS) was developed by an international team with subsystem contributions from NASA GSFC and is part of CAssini's Plasma Spectrometer or CAPS. Using a unique electric field configuration and precise timing, the IMS can accurately detect several species of ions over a large energy range (1 eV – 50 keV). Cassini is currently at ~8 AU, traveling towards Saturn, and can therefore take measurements of the interplanetary solar wind.

Interstellar neutral gas is flowing into the inner solar system due to the sun's movement through the Interstellar Medium (ISM). These neutrals are photoionized near the sun and join the solar wind. The number and incident direction of these Interstellar Pickup Ions (IPIs) can tell us about the ISM. We can detect IPIs because perpendicular electric and magnetic fields cause them to gyrate (see Figure 1), giving them a unique velocity distribution (see Figure 2).

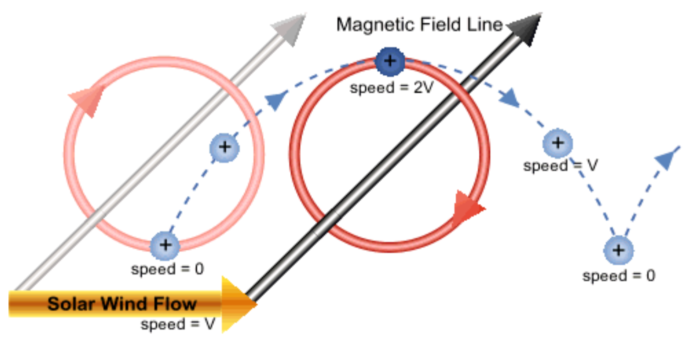


Figure 1: Interstellar Pickup Ions in the Solar Wind

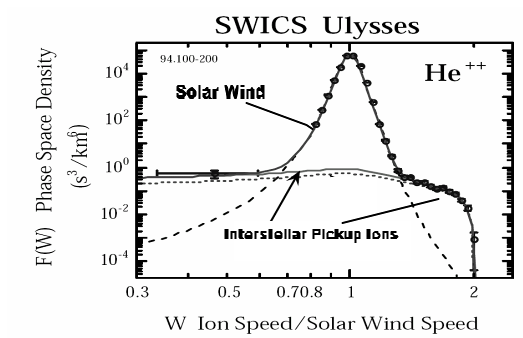


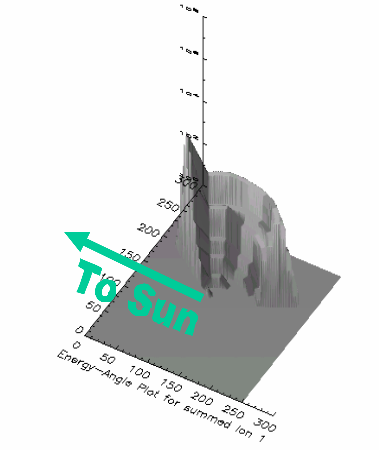
Figure 2: Phase Space Density graph, modified from Gloeckler & Geiss, 1998.

Personal Contributions – Programming in Interactive Data Language (IDL)

- *Predicting Ion Trajectories* – One program generates different IPI trajectories assuming a simple model of constant solar wind velocity and a perpendicular magnetic field. This is useful when trying to determine the initial distribution of IPIs.
- *Data Analysis* – Another program takes raw "A-cycle" data files, each representing 32 seconds of observation, and adds the ion counts together appropriately. Since we are searching for a small number of IPIs, data from an entire day (thousands of files) are summed. After summing the data, several useful graphs are generated:
  - Spatial direction of each of the IMS sectors relative to the sun (includes spacecraft position, orientation, actuator position, etc.) as they change in time
  - Energy-angle phase diagrams, showing the energy distribution for each ion by angle (Figure 3)
  - Average Energy of each ion and each sector, as it changes in time (Figure 4)
  - Velocity Dispersions of each ion and each sector
  - Phase Space Density diagrams, showing velocity vs. the phase space density (as in Figure 2 above, Figure 5 below)

  In addition, the program also:
  - Calculates the value of several parameters for each ion: number of counts, average and standard deviation of energy and velocity, solar wind speed, sound speed, Mach number, temperature, number density of ions, etc.
  - Generates an index file for later use, increasing program efficiency and reducing computation time
- *Observations* – Thus far, all of the analysis has focused on 500 bps proton data from two time periods (9/10/02 – 9/12/02 and 01/17/03-01/19/03). Much of the work has focused on a heating event on 09/11/02. The average velocity and velocity spread increase significantly, and there is clear evidence of accelerated protons (not necessarily IPIs). The following diagrams (Figures 3-5) come from data taken after this event. From these graphs, we see an unusually wide range of velocities and angles represented; this indicates heating, although the presence of counts in the other angular bins may be due to crosstalk.

Figure 3: Energy-Angle Phase Diagram. The axes are labeled with arbitrary pixel numbers.



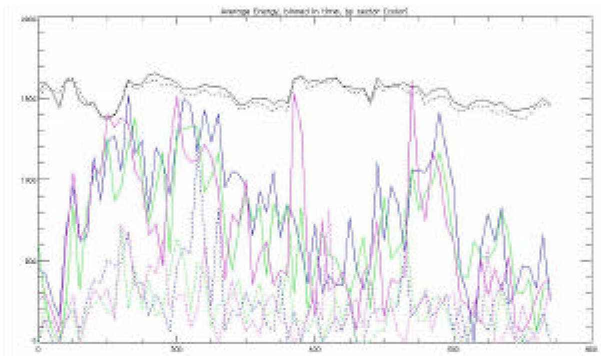
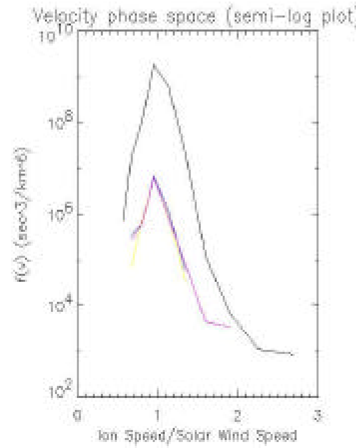


Figure 4: Average Energy (eV) changing in time

Figure 5: Phase Space Density Graph



Conclusions

- IDL programs effectively summarize Cassini IMS data, allowing for a deeper understanding of the solar wind intensity, velocity, and direction.
- Some data show instability, heating, and/or shocks making IPIs harder to identify and characterize.
- Interstellar Pickup Ions are very rare (as expected), and large amounts of data (~100 days) must be carefully summed.

Future Steps

- Expanding the capabilities of the IDL programs developed (higher bandwidths, more ions, more autonomous, etc.)
- Summing larger amounts of data (~100 days), sifting out Interstellar Pickup Ions, and plotting them in phase space
- Characterizing the number and shape (shell or ring) of the initial distribution of IPIs
- Refining current theories about the solar wind, ISM, and IPIs to match observations

Selected References

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